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Appendix E

Sensitivity Analysis

APPENDIX E
SENSITIVITY ANALYSIS

Sensitivity analyses were conducted to determine effects of changes in thickness of the silt loam layer, increased precipitation, and changes in meteorological factors on the cover's performance. This section specifically addresses sensitivity of the cover to the variations mentioned above. Long-term cover performance issues to which these analyses also apply are addressed in other studies including the "Landfill Compaction/Subsidence Study," (DOE-ID 2001b) and the "Liner and Final Cover Long-Term Performance Evaluation and Final Cover Life Cycle Expectation" (DOE-ID 2001a).

E.1. THICKNESS SENSITIVITY OF WATER STORAGE LAYER

Changes in thickness of the silt loam layer of the water storage section were evaluated using the average and extreme weather scenarios. Initial conditions for each cover thickness were developed by running the model to a quasi-steady state over the simulation period and using the ending suctions as the initial conditions for the final runs, as was done for the base simulation. The model was then run for the full simulation period and the final conditions from the average weather condition model were used as the initial conditions for the extreme weather condition models. The silt loam layer of the covers modeled ranged from 0.25 to 3.5 m. The results of these runs are shown in Figure E-1.

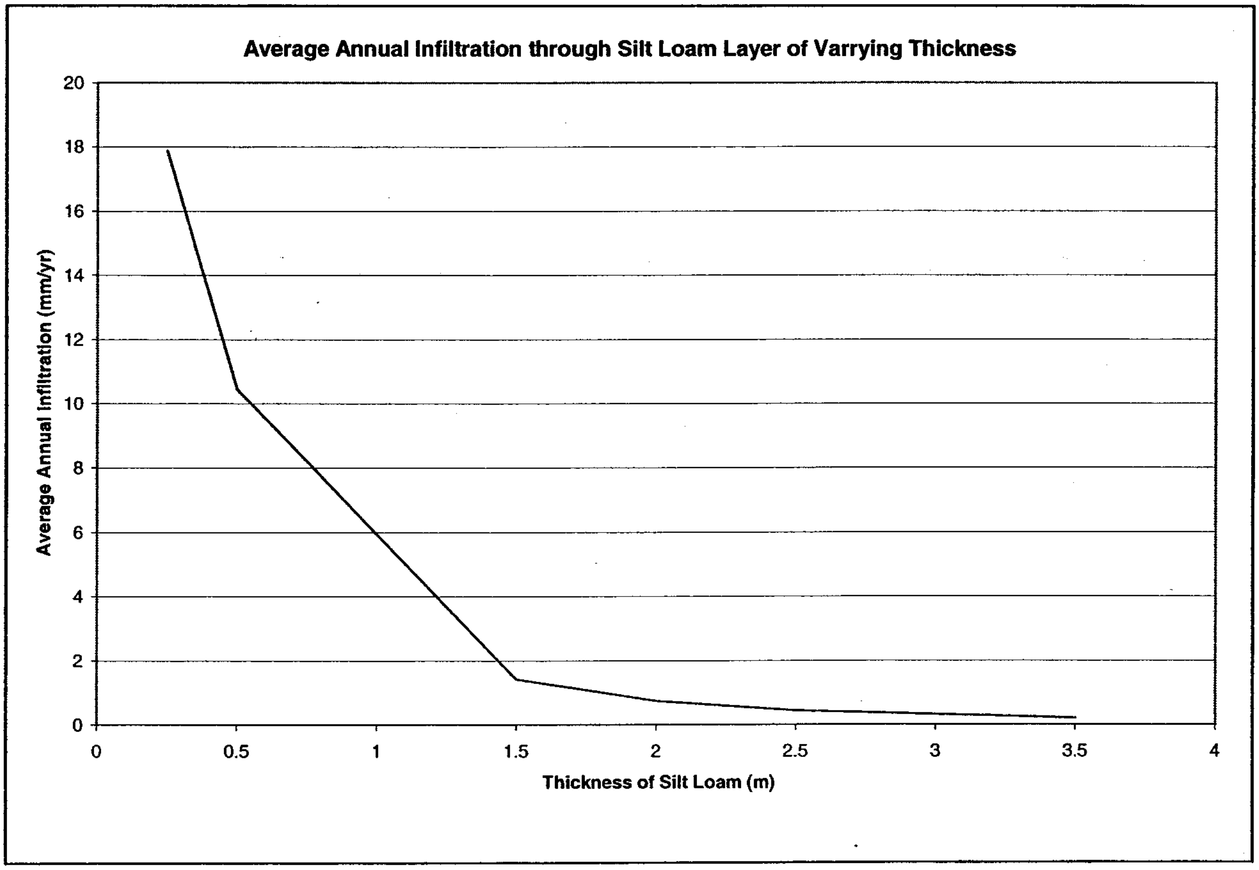

Figure E-1. Increase in infiltration resulting from 10% reduction in thickness of the clay barrier.

As shown in Figure E-1, increasing the thickness beyond 2 m results in minimal reduction in infiltration. From observation of Figure 2-5, the optimal water storage layer thickness is between 1.5 and 2 m. Insignificant changes in infiltration occur for the water storage layer thickness beyond 2 m. The minimum effective thickness of the silt loam layer is 2 m. The detailed computer model run summary sheets are provided at the end of this appendix.

E.2. PRECIPITATION SENSITIVITY

The effect of increased precipitation on infiltration through the water storage layer of the cover was analyzed using an average year of weather and repeating that weather scenario until the soil profile reached a quasi-steady state. The year with total precipitation closest to average was 1975, which had 269 mm of precipitation including 51 mm of water equivalent snowfall. The average precipitation for the period of record is 218 mm per year including 37 mm of water equivalent snowfall. This weather set is included in the base case scenario and included in Appendix B.

The one-dimensional computer model was run using one, two, three, and four times the 1975 precipitation. Twenty years were modeled for each precipitation interval using two 10-year simulations. Initial conditions for the first simulation were the same as the final conditions from the base case scenario modeled previously. Final conditions from the first simulation were used as the initial conditions for the second simulation.

The quasi-steady state was determined by the change in the sum of the infiltration through the silt loam and the evapotranspiration at the end of each year modeled. When the annual change in this sum approximated the water balance error for the model, the system was determined to be in a quasi-steady state.

The results of the precipitation sensitivity analyses are given in Table E-2 and shown in Figure E-2. Run Summary sheets for these simulations are included at the end of this appendix. The four times average precipitation scenario resulted in breakthrough of the water storage layer and the majority of the moisture that infiltrated through the water storage in the biointrusion layer. The moisture storage in the biointrusion layer and bottom boundary condition resulted in a different flux from the observation node and located at the bottom of the water storage layer and node at the bottom of the modeled profile (biointrusion layer). This difference in flux may have influenced the infiltration through the water storage layer. Therefore there is some degree of uncertainty in the results from the four times simulation. For this reason, results from the four times precipitation models were considered approximate and are not included in the table. The value shown in the figure is approximated result from the four times precipitation simulations.

Table E-1. Annual infiltration results from 1975 weather data.

	1 Times Precipitation		2 Times Precipitation		3 Times Precipitation		4 Times Precipitation	
Year	% Change[1]	Infiltration (mm/year)	% Change	Infiltration (mm/year)	% Change	Infiltration (mm/year)	% Change	Infiltration (mm/year)
1	-	0.120	-	-0.638	-	-7.756	-	-10.239
2	-0.25	0.040	-4.78%	-6.086	-19.11	-4.519	-26.19	-101.254
3	-0.15	-0.047	-2.63	-2.899	-7.13	-2.126	-2.85	-109.747
4	-0.07	-0.122	-4.08	-1.578	-1.09	-1.03	-0.32	-112.842
5	-0.03	-0.137	-2.23	-0.975	-0.20	-0.518	-0.47	-135.531
6	-0.02	-0.145	-0.94	-0.644	-0.04	-0.288	0.43	-130.937

Table E-1. (continued).

	1 Times Precipitation		2 Times Precipitation		3 Times Precipitation		4 Times Precipitation	
Year	% Change[1]	Infiltration (mm/year)	% Change	Infiltration (mm/year)	% Change	Infiltration (mm/year)	% Change	Infiltration (mm/year)
7	-0.01	-0.147	-0.35	-0.521	-0.01	-0.201	-0.02	-131.604
8	-0.01	-0.151	-0.13	-0.467	-0.01	-0.173	0.02	-131.723
9	-0.01	-0.153	-0.04	-0.417	0.00	-0.156	-0.01	-132.121
10	-0.01	-0.156	-0.01	-0.369	0.00	-0.146	0.02	-132.059
11	0.00	-0.155	0.00	-0.337	0.00	-0.149	0.01	-132.056
12	0.00	-0.154	0.00	-0.336	0.00	-0.136	0.00	-132.02
13	0.00	-0.154	0.00	-0.332	0.00	-0.148	0.00	-132.012
14	-0.01	-0.153	-0.01	-0.328	0.00	-0.144	0.00	-132.015
15	0.00	-0.153	0.00	-0.325	0.00	-0.136	0.00	-132.028
16	0.00	-0.153	0.00	-0.322	0.00	-0.137	0.00	-132.038
17	0.00	-0.151	0.00	-0.321	0.00	-0.129	0.00	-132.04
18	-0.01	-0.150	0.00	-0.323	0.00	-0.136	0.00	-132.028
19	0.00	-0.150	0.00	-0.32	0.00	-0.124	0.00	-132.012
20	0.03	-0.149	0.00	-0.318	0.06	-0.135	0.04	-132.071

Notes:

1. Percent change is the sum of the infiltration and evapotranspiration divided by the sum from the previous year.
2. Negative values indicate upward flow.
3. Shaded cells indicated the year of quasi-steady state conditions.

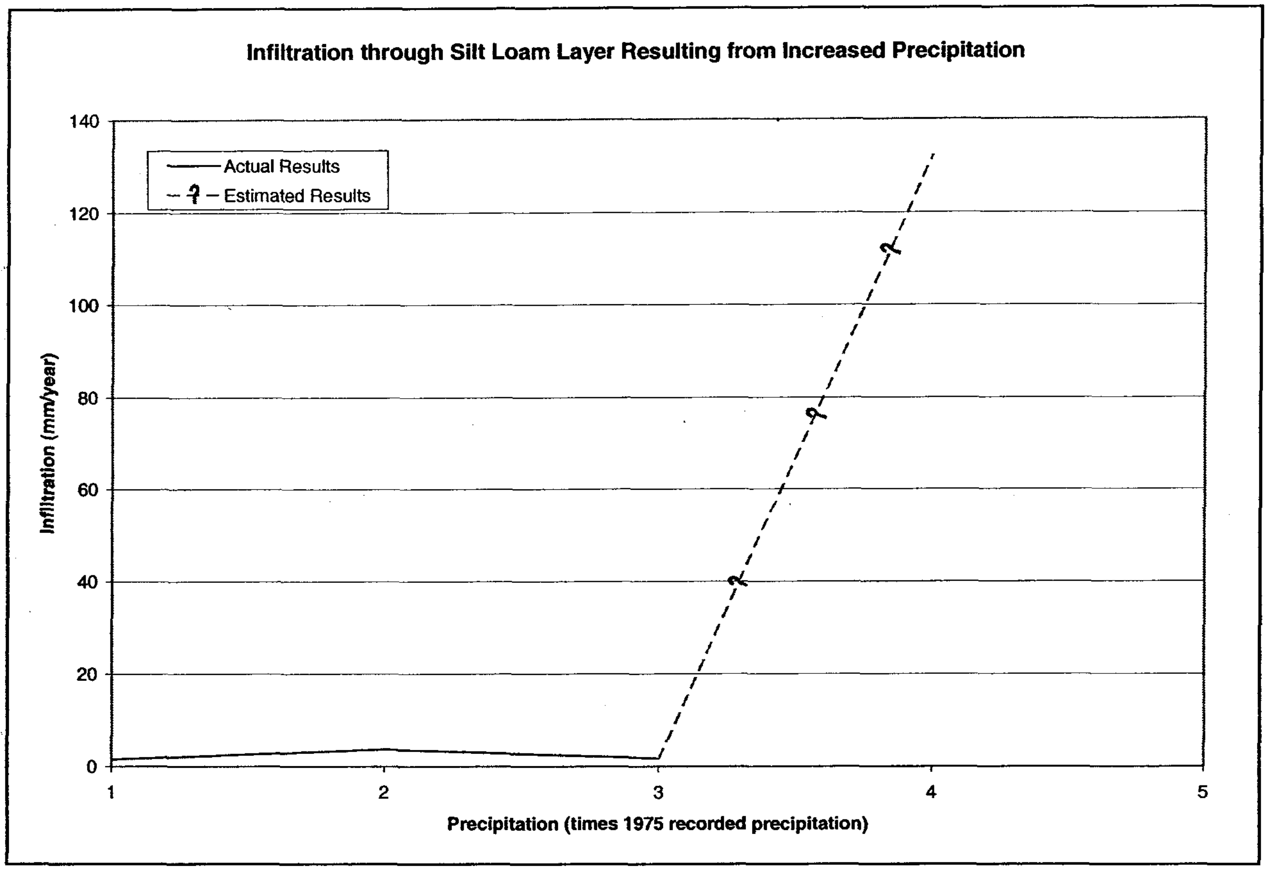

Figure E-2. Infiltration through silt loam layer resulting from increased precipitation.

From observation of Figure E-2, the proposed cover remains effective to three times the average annual precipitation. Three times the precipitation, 810 mm, is roughly equivalent to the annual precipitation in Detroit, Michigan, 828 mm. Four times the precipitation, 1,080 mm, is similar to the precipitation in New York, New York, 1,070 mm.

The infiltration at twice the recorded precipitation was 0.369 mm/year the infiltration dropped at three times recorded precipitation to 0.173 mm/year. This is the result of increased transpiration. At twice the recorded precipitation, transpiration removed 18.1% (97.4 mm) of the annual precipitation from the cover. At three times the recorded precipitation, transpiration removed 29.5% (238.6 mm) of the annual precipitation from the cover. This is a result of the vegetation properties. When the matric suction in the soil is between 100 and 1500 kPa, the vegetation reduces activity to conserve water and transpiration decreases. When the matric suction is less than 100 kPa (moisture content of the soil is higher), the vegetation is at full activity resulting in increased transpiration. At three times the recorded precipitation, the soil maintains a suction below 100 kPa for more of the growing season resulting in an increase in transpiration.

E.3. RUN SUMMARY SHEETS

E.3.1 Thickness Sensitivity Run Summary Sheets

0.25 Meter Thick Silt Loam Layer with Base Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: _25metera

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes   b) Freeze/Thaw: Yes   c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
93	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	2370.09	b) Net cumulative infiltration (mm):	123.28
c) Net cumulative bottom flux (mm):	0.62	d) Net cumulative runoff (mm):	0
e) Net cumulative PE (mm):	-11700.73	f) Net cumulative AE (mm):	-2246.81
g) Net cumulative PT (mm):	-3813.91	h) Net cumulative AT (mm):	-124.08
i) Net cumulative ET (mm):	-2370.89	j) Net cum. user monitor flx (mm):	0.61
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	0.06

User Node: 32

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

0.25 Meter Thick Silt Loam Layer with Extreme Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: _25MetExa

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes   b) Freeze/Thaw: Yes   c) Years: 4

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
93	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-56
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100
c) Moisture wilting point (kPa):	1500
e) Grass quality:	Poor
b) First date of growing season:	15-Apr-57
d) Last date of growing season:	01-Oct-57
f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	1352.81
c) Net cumulative bottom flux (mm):	0.63
e) Net cumulative PE (mm):	-5532.37
g) Net cumulative PT (mm):	-1757.54
i) Net cumulative ET (mm):	-1354.78
k) Net cumulative drain node flux (m	0
b) Net cumulative infiltration (mm):	120.97
d) Net cumulative runoff (mm):	0
f) Net cumulative AE (mm):	-1231.83
h) Net cumulative AT (mm):	-122.94
j) Net cum. user monitor flx (mm):	1.58
l) Net cum. user monitor flx (mm/yr):	0.4

User Node: 32
User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.
Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

0.5 Meter Thick Silt Loam Layer with Base Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: 0_5metera

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes | b) Freeze/Thaw: Yes | c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
89	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100
c) Moisture wilting point (kPa):	1500
e) Grass quality:	Poor
b) First date of growing season:	15-Apr-67
d) Last date of growing season:	01-Oct-67
f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	2370.09
c) Net cumulative bottom flux (mm):	-2.53
e) Net cumulative PE (mm):	-11702.18
g) Net cumulative PT (mm):	-3814.3
i) Net cumulative ET (mm):	-2368.56
k) Net cumulative drain node flux (m	0
b) Net cumulative infiltration (mm):	125.68
d) Net cumulative runoff (mm):	1.49
f) Net cumulative AE (mm):	-2242.93
h) Net cumulative AT (mm):	-125.63
j) Net cum. user monitor flx (mm):	-1.73
l) Net cum. user monitor flx (mm/yr):	-0.17

User Node: 30

User Elev: 153.70 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

0.5 Meter Thick Silt Loam Layer with Extreme Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: 0_5MetExa

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes | b) Freeze/Thaw: Yes | c) Years: 4

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
89	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-56
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100
c) Moisture wilting point (kPa):	1500
e) Grass quality:	Poor
b) First date of growing season:	15-Apr-57
d) Last date of growing season:	01-Oct-57
f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	1352.81
c) Net cumulative bottom flux (mm):	-0.17
e) Net cumulative PE (mm):	-5532.87
g) Net cumulative PT (mm):	-1757.72
i) Net cumulative ET (mm):	-1357.86
k) Net cumulative drain node flux (m	0
b) Net cumulative infiltration (mm):	118.5
d) Net cumulative runoff (mm):	0
f) Net cumulative AE (mm):	-1234.3
h) Net cumulative AT (mm):	-123.56
j) Net cum. user monitor flx (mm):	1.85
l) Net cum. user monitor flx (mm/yr):	0.46

User Node: 28

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1.5 Meter Thick Silt Loam Layer with Base Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: 1_5meter

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes b) Freeze/Thaw: Yes c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
93	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100
c) Moisture wilting point (kPa):	1500
e) Grass quality:	Poor
b) First date of growing season:	15-Apr-67
d) Last date of growing season:	01-Oct-67
f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	2370.09
c) Net cumulative bottom flux (mm):	-1.35
e) Net cumulative PE (mm):	-11701.94
g) Net cumulative PT (mm):	-3814.09
i) Net cumulative ET (mm):	-2348.18
k) Net cumulative drain node flux (m	0
b) Net cumulative infiltration (mm):	130.87
d) Net cumulative runoff (mm):	11.34
f) Net cumulative AE (mm):	-2227.89
h) Net cumulative AT (mm):	-120.28
j) Net cum. user monitor flx (mm):	-4.85
l) Net cum. user monitor flx (mm/yr):	-0.49

User Node: 32

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1.5 Meter Thick Silt Loam Layer with Extreme Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: 1_5MetExa

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes   b) Freeze/Thaw: Yes   c) Years: 4

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
93	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-56
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-57
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-57
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	1352.81	b) Net cumulative infiltration (mm):	123.41
c) Net cumulative bottom flux (mm):	-0.69	d) Net cumulative runoff (mm):	0
e) Net cumulative PE (mm):	-5533.12	f) Net cumulative AE (mm):	-1229.4
g) Net cumulative PT (mm):	-1757.67	h) Net cumulative AT (mm):	-117.27
i) Net cumulative ET (mm):	-1346.66	j) Net cum. user monitor flx (mm):	-2.32
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr)	-0.58

User Node: 32

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

2.5 Meter Thick Silt Loam Layer with Base Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: 2_5meter

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes   b) Freeze/Thaw: Yes   c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	2370.09	b) Net cumulative infiltration (mm):	130.75
c) Net cumulative bottom flux (mm):	-0.84	d) Net cumulative runoff (mm):	15.89
e) Net cumulative PE (mm):	-11702.15	f) Net cumulative AE (mm):	-2223.45
g) Net cumulative PT (mm):	-3814.24	h) Net cumulative AT (mm):	-119.89
i) Net cumulative ET (mm):	-2343.35	j) Net cum. user monitor flx (mm):	-2.7
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-0.27

User Node: 42

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

2.5 Meter Thick Silt Loam Layer with Extreme Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: 2_5MetExa

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes   b) Freeze/Thaw: Yes   c) Years: 4

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-56
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-57
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-57
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	1352.81	b) Net cumulative infiltration (mm):	118.54
c) Net cumulative bottom flux (mm):	-0.66	d) Net cumulative runoff (mm):	2.98
e) Net cumulative PE (mm):	-5532.9	f) Net cumulative AE (mm):	-1231.29
g) Net cumulative PT (mm):	-1757.64	h) Net cumulative AT (mm):	-117.09
i) Net cumulative ET (mm):	-1348.37	j) Net cum. user monitor flx (mm):	-1.03
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-0.26

User Node: 42

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

3.5 Meter Thick Silt Loam Layer with Base Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: 3_5metera

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes | b) Freeze/Thaw: Yes | c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
97	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	2370.09	b) Net cumulative infiltration (mm):	128.37
c) Net cumulative bottom flux (mm):	-0.71	d) Net cumulative runoff (mm):	16.02
e) Net cumulative PE (mm):	-11702.4	f) Net cumulative AE (mm):	-2225.7
g) Net cumulative PT (mm):	-3814.17	h) Net cumulative AT (mm):	-117.59
i) Net cumulative ET (mm):	-2343.3	j) Net cum. user monitor flx (mm):	-1.71
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-0.17

User Node: 58

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

3.5 Meter Thick Silt Loam Layer with Extreme Case Weather Scenario

SoilCover 2000 Run Summary Page

1. Project Name: 3_5MetExa

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes — b) Freeze/Thaw: Yes — c) Years: 4

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
97	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-56
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-57
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-57
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	1352.81	b) Net cumulative infiltration (mm):	120.04
c) Net cumulative bottom flux (mm):	-0.44	d) Net cumulative runoff (mm):	3.21
e) Net cumulative PE (mm):	-5532.9	f) Net cumulative AE (mm):	-1229.55
g) Net cumulative PT (mm):	-1757.63	h) Net cumulative AT (mm):	-118.57
i) Net cumulative ET (mm):	-1348.12	j) Net cum. user monitor flx (mm):	-0.34
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-0.09

User Node: 58

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

E.3.2 Precipitation Sensitivity Run Summary Sheets

1975 Weather Data – first ten-year run

SoilCover 2000 Run Summary Page

1. Project Name: Precip1x3

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes   b) Freeze/Thaw: No   c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	2692.4	b) Net cumulative infiltration (mm):	92.63
c) Net cumulative bottom flux (mm):	-1.3	d) Net cumulative runoff (mm):	0
e) Net cumulative PE (mm):	-11829.17	f) Net cumulative AE (mm):	-2599.77
g) Net cumulative PT (mm):	-4290.15	h) Net cumulative AT (mm):	-85.31
i) Net cumulative ET (mm):	-2685.08	j) Net cum. user monitor flx (mm):	-1.01
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-0.1

User Node: 38
User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.
Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1975 Weather Data – second ten-year run

SoilCover 2000 Run Summary Page

1. Project Name: Precip1x3a

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes b) Freeze/Thaw: No c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100
c) Moisture wilting point (kPa):	1500
e) Grass quality:	Poor
b) First date of growing season:	15-Apr-67
d) Last date of growing season:	01-Oct-67
f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	2692.4
c) Net cumulative bottom flux (mm):	-1.38
e) Net cumulative PE (mm):	-11828.72
g) Net cumulative PT (mm):	-4290.1
i) Net cumulative ET (mm):	-2687.93
k) Net cumulative drain node flux (m	0
b) Net cumulative infiltration (mm):	90.15
d) Net cumulative runoff (mm):	0
f) Net cumulative AE (mm):	-2602.25
h) Net cumulative AT (mm):	-85.68
j) Net cum. user monitor flx (mm):	-1.62
l) Net cum. user monitor flx (mm/yr):	-0.16

User Node: 38

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1975 Weather Data with Two Times Recorded Precipitation – first ten-year run

SoilCover 2000 Run Summary Page

1. Project Name: Precip2x3

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes | b) Freeze/Thaw: No | c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	5384.81	b) Net cumulative infiltration (mm):	1081.91
c) Net cumulative bottom flux (mm):	-1.59	d) Net cumulative runoff (mm):	0
e) Net cumulative PE (mm):	-11834.36	f) Net cumulative AE (mm):	-4302.9
g) Net cumulative PT (mm):	-4293.69	h) Net cumulative AT (mm):	-864.89
i) Net cumulative ET (mm):	-5167.79	j) Net cum. user monitor flx (mm):	-14.57
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-1.46

User Node: 38

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1975 Weather Data with Two Times Recorded Precipitation – second ten-year run

SoilCover 2000 Run Summary Page

1. Project Name: Precip2x3a

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes   b) Freeze/Thaw: No   c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	5384.81	b) Net cumulative infiltration (mm):	980.38
c) Net cumulative bottom flux (mm):	-1.81	d) Net cumulative runoff (mm):	0
e) Net cumulative PE (mm):	-11834.73	f) Net cumulative AE (mm):	-4404.43
g) Net cumulative PT (mm):	-4293.8	h) Net cumulative AT (mm):	-973.94
i) Net cumulative ET (mm):	-5378.37	j) Net cum. user monitor flx (mm):	-3.64
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr)	-0.36

User Node: 38

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1975 Weather Data with Three Times Recorded Precipitation– first ten-year run

SoilCover 2000 Run Summary Page

1. Project Name: Precip3x3

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes | b) Freeze/Thaw: No | c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	8077.19	b) Net cumulative infiltration (mm):	2522.21
c) Net cumulative bottom flux (mm):	-1.58	d) Net cumulative runoff (mm):	0
e) Net cumulative PE (mm):	-11847.67	f) Net cumulative AE (mm):	-5554.98
g) Net cumulative PT (mm):	-4299.65	h) Net cumulative AT (mm):	-2235.29
i) Net cumulative ET (mm):	-7790.27	j) Net cum. user monitor flx (mm):	-16.9
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-1.69

User Node: 38
User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.
Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1975 Weather Data with Three Times Recorded Precipitation – second ten-year run

SoilCover 2000 Run Summary Page

1. Project Name: Precip3x3a

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes | b) Freeze/Thaw: No | c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100
c) Moisture wilting point (kPa):	1500
e) Grass quality:	Poor
b) First date of growing season:	15-Apr-67
d) Last date of growing season:	01-Oct-67
f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	8077.19
c) Net cumulative bottom flux (mm):	-1.77
e) Net cumulative PE (mm):	-11849.15
g) Net cumulative PT (mm):	-4300.32
i) Net cumulative ET (mm):	-8066.78
k) Net cumulative drain node flux (m	0
b) Net cumulative infiltration (mm):	2395.73
d) Net cumulative runoff (mm):	0
f) Net cumulative AE (mm):	-5681.47
h) Net cumulative AT (mm):	-2385.31
j) Net cum. user monitor flx (mm):	-1.11
l) Net cum. user monitor flx (mm/yr):	-0.11

User Node: 38

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1975 Weather Data with Four Times Recorded Precipitation – first ten-year run

SoilCover 2000 Run Summary Page

1. Project Name: Precip4x3

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes   b) Freeze/Thaw: No   c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	10769.61	b) Net cumulative infiltration (mm):	4381.02
c) Net cumulative bottom flux (mm):	-1.68	d) Net cumulative runoff (mm):	0
e) Net cumulative PE (mm):	-11859.74	f) Net cumulative AE (mm):	-6388.6
g) Net cumulative PT (mm):	-4305.54	h) Net cumulative AT (mm):	-2940.02
i) Net cumulative ET (mm):	-9328.62	j) Net cum. user monitor flx (mm):	-1128.15
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-112.82

User Node: 38

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

1975 Weather Data with Four Times Recorded Precipitation – second ten-year run

SoilCover 2000 Run Summary Page

1. Project Name: Precip4x3a

2. Project Directory: d:\soilcov\

3. Run Parameters:

a) Vegetation: Yes b) Freeze/Thaw: No c) Years: 10

4. Mesh Information:

a) Convergence Criteria:

Max. Iterations	Max.Change Suction (%)	Max.Change Temperature (%)	Suction Dampening (%)	Temperature Dampening (%)
100	1	1	3	3

b) Time Step Control:

Max.Change Suction (%)	Max.Change Temperature (%)	Minimum Time Step (secnds)	First Time Step (secnds)	Maximum Time Step (secnds)
5	5	1	1	3000

c) Soil Profile Data:

Number of Nodes	Number of Layers	Drain Node	Drain Flux (mm/day)
99	4	2	0

5. Soil Property Summary:

Soil Name	Porosity	Spec. Grav.	Mv (1/kPa)	Ksat (cm/s)
Silty Loam	0.441	2.65	2.60E-03	5.00E-04
coarse sand	0.265	2.65	9.10E-06	1.00E-02
Fine Sand	0.387	2.63	9.10E-06	1.00E-03
cobble	0.265	2.65	9.10E-06	1.00E-01
name5				
name6				
name7				
name8				

6. Boundary Conditions

a) First date of run each year:	01-Oct-66
b) Total run days/year:	365
c) Top temperature condition:	Computed
d) Bottom temperature (C):	4
e) Day 1 top moisture condition:	Precip.
f) Day 1 bot. moisture condition:	-1
g) Day 1 bottom moisture value:	-1

7. Vegetation Summary:

a) Moisture limiting point (kPa):	100	b) First date of growing season:	15-Apr-67
c) Moisture wilting point (kPa):	1500	d) Last date of growing season:	01-Oct-67
e) Grass quality:	Poor	f) First day root depth (cm):	1

8. Run Output Summary:

a) Net cumulative precipitation (mm)	10769.61	b) Net cumulative infiltration (mm):	4331.84
c) Net cumulative bottom flux (mm):	-23.76	d) Net cumulative runoff (mm):	0
e) Net cumulative PE (mm):	-11858.91	f) Net cumulative AE (mm):	-6437.78
g) Net cumulative PT (mm):	-4304.62	h) Net cumulative AT (mm):	-2980.97
i) Net cumulative ET (mm):	-9418.75	j) Net cum. user monitor flx (mm):	-1320.36
k) Net cumulative drain node flux (m	0	l) Net cum. user monitor flx (mm/yr):	-132.04

User Node: 38

User Elev: 155.00 cm

Note: Positive fluxes at interior nodes are UPWARDS. Negative fluxes at surface or base are LEAVING the mesh.

Note: Net Cumulative Infiltration is at the surface and does NOT include root uptake (if any). You must add it accordingly if checking the surface water balance.

E.4. VERIFICATION OF MODEL RESULTS

The following calculation was performed to validate the results from the hydrologic modeling.

Analytical Verification of SoilCover Model

OBJECTIVE: Use a simple analytical solution to verify the breakthrough flux from the water storage layer predicted by the SoilCover Model.

METHOD: Use the equation from the text "Flow of Water in the Vadose Zone" chapter 3 to determine the precipitation required to breakthrough the upper section of the cover.
The formula is given below.

q~[hae]Kstan(phi)/L

L = Length of cover
hae = Air entry head for the silty loam soil. Use the "a" curve fit parameter for the Fredlund and Xing equation (Appendix C EDF-279)
Ks = Saturated conductivity of the silty loam layer
phi = slope of the cover
q = Vertical precipitation flux required for breakthrough

Calculation:

hae =	15.84 kpa	See page C-34 of Appendix C - EDF-279
Ks =	0.0005 cm/sec	See page C-34 of Appendix C - EDF-279
Cover slope =	3 %	
q =	0.04 mm/yr	See page 4-2 of EDF-279
Unit Conversions		
hae =	63.69264	kpa x 4.021 = inches of H2O
hae =	1.6 m	inches of H20 x .0254 m/inch = meters of H2O
Ks	0.000005 m/sec	
Cover slope	1.72 degrees	
L =	122 meters	EDF 279

L (meters)	q m/sec	q mm/year
122.0	2E-09	63

Results
It would require 63 mm/year of vertical precipitation flux to breakthrough the cover . This supports the model that breakthrough will occur at greater than 3x recorded precipitation.

Assumptions

1. The flow is steady
2. The primary lateral driving force for flow is gravity.
3. The flow is parallel to the interface between the silty loam and coarse layers.
4. The flow is vertical above the capillary fringe
5. The cover must be saturated for breakthrough to occur.

References

Selker, J.S., Keller, C.K., and McCord, J.T., "Vadose Zone Processes"

EDF-ER-279, 2001, “Hydrologic Modeling of Final Cover,” Rev. 2, Draft A, Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, October 2001.

E.5. SENSITIVITY OF THE MODIFIED PENMAN EQUATION TO METEOROLOGICAL CHANGES

The Modified Penman Equation was evaluated for sensitivity to changes in a number of meteorological factors, including temperature, net radiant energy, wind speed, and relative humidity. The Modified Penman Equation models the amount of water that will evaporate based on the conditions of the atmosphere and amount of water available at the soil surface. The SoilCover 2000™ model continuously updates the input values for the equation, including the relative humidity of the soil surface. For the purposes of this analysis we have assumed that the soil surface is always saturated. The relative humidity of the soil surface then is 1.0 and the equation gives potential evaporation, which is significantly higher than the actual evaporation calculated by the model.

E.5.1 Meteorological Factor Graphs

The sensitivity of the equation to changes in the individual components was analyzed by holding all of the other factors constant and plotting the resulting changes in potential evaporation. The results of these calculations were plotted with comparisons to other locations and a 3X reduction. Graphs of changes in temperature, net radiant energy, wind speed, and relative humidity are presented in Figures E-3, E-4, E-5, and E-6, respectively.

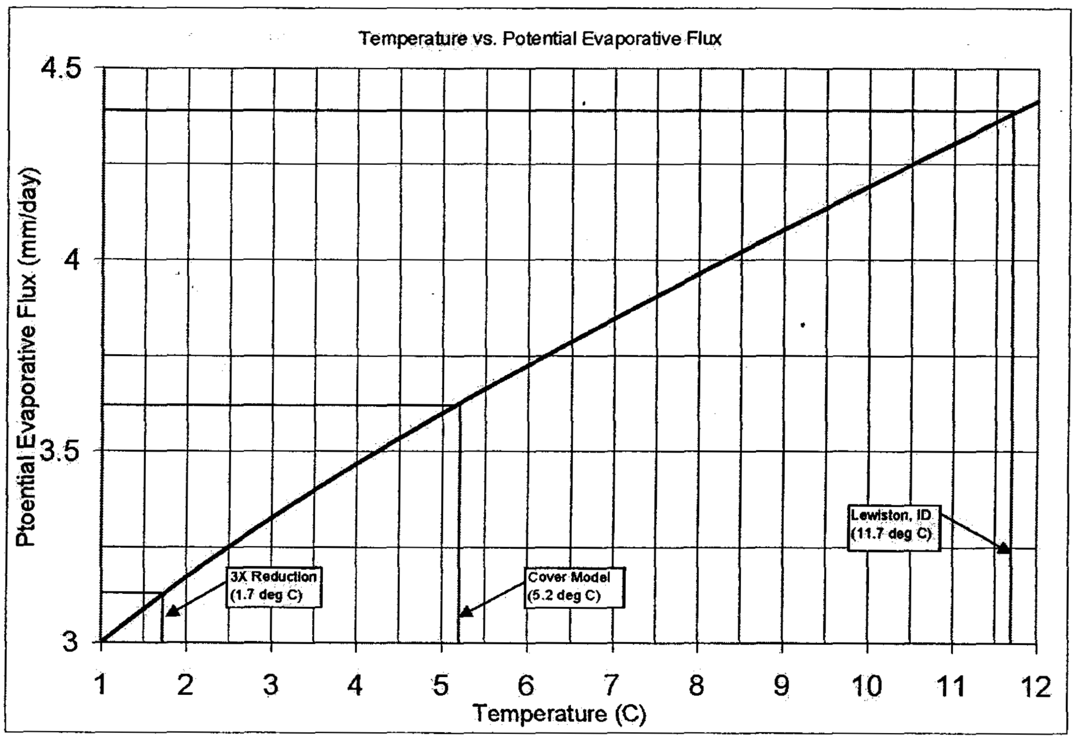

Figure E-3. Effect of Temperature on Potential Evaporation.

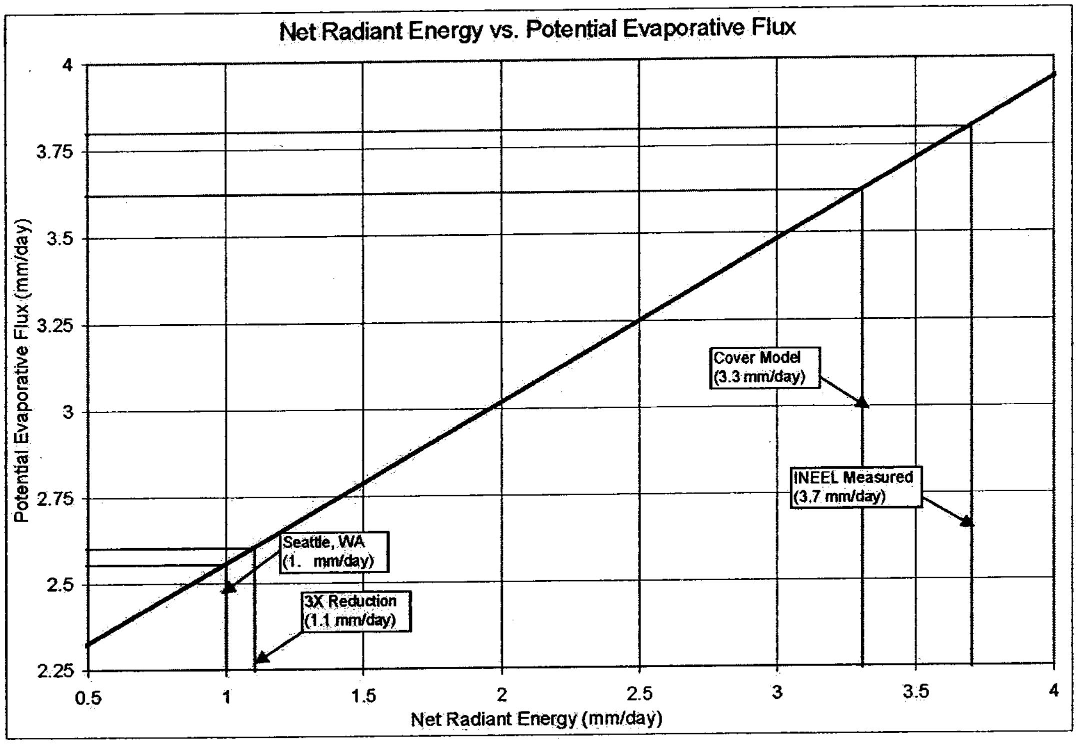

Figure E-4. Effect of Net Radiant Energy of Potential Evaporation.

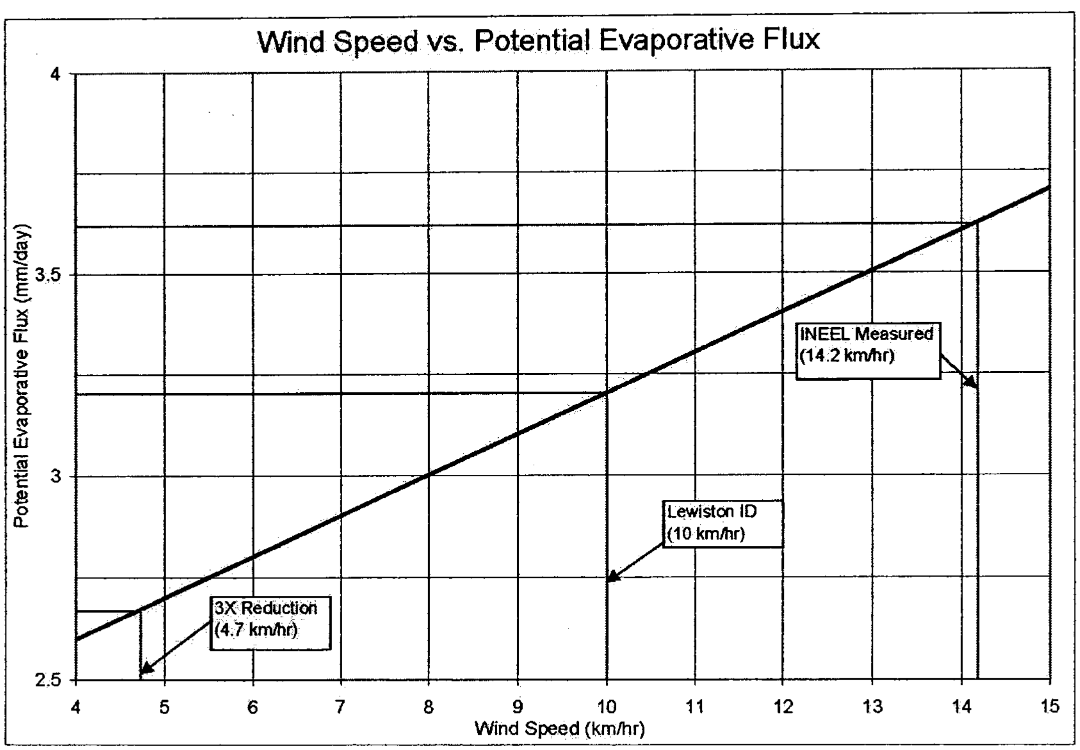

Figure E-5. Effect of Wind Speed on Potential Evaporation.

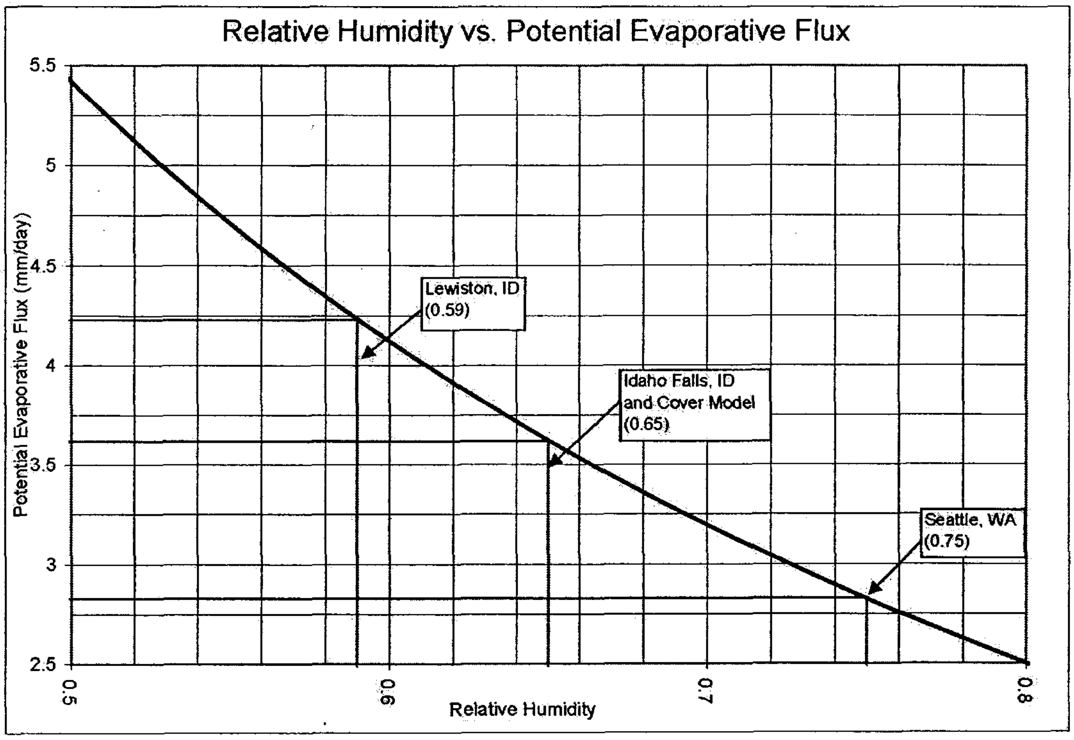

Figure E-6. Effect of Relative Humidity on Potential Evaporation

E.4.2 Meteorological Reduction Factors

A 3X reduction was then used to calculate a reduced value for temperature, net radiant energy, and wind speed. A 3X increase in relative humidity resulted in a value of 1.95. Since relative humidity cannot increase above 1.0, the value for Seattle, WA, 0.75, was used. These reduced values were used to calculate reduced evaporation rates, which were then used to calculate reduction factors for each input, shown in table E-2.

Table E-2. Calculated evaporation rates and reduction factors.

Factor	INEEL Potential Evaporation (mm/day)	Reduced Potential Evaporation (mm/day)	Reduction Factor
Temperature	3.62	3.13	0.86
Net Radiant Energy	3.62	2.60	0.72
Wind Speed	3.62	2.67	0.74
Relative Humidity	3.62	2.83	0.78

E.4.3 Reduction Factor Calculation

The following calculation generates the values in Table E-2.

Prepared By: B.G. Adams 2/7
Date: 3-18-02
Checked By: John Pellicer
Date: 19-Mar-2002

Title:

Calculate the potential evaporation at the ICDF for reduced meteorological factors.

Purpose:

Find percent reduction of evaporation for reductions in temperature, net radiant energy, and wind speed. In addition find a reduction factor for an increase in relative humidity, using the Modified Penman Equation for potential evaporation.

References:

Allen, et. al., Crop Evapotranspiration, FAO Irrigation and Drainage Paper 56, FAO-Food and Agriculture Organization of the United Nations, Rome 1998, www.fao.org/docrep/X0490e/X0490e00.htm

CRC Handbook of Chemistry and Physics, 66th Edition, CRC Press, Inc., Boca Raton, FL

Input:

INEEL average values used for modeling:

Temperature, T = 5.15 °C
Net radiant energy, Q = 8.23 MJ/m^2-day = 3.31 mm/day
Wind Speed, Ua = 14.18 km/hr
Relative Humidity, Hr = 0.65
Vapor Saturation Pressure, Pa from table 2.3, page(6/8)
Psychometric Constant, ν = 0.056 kPa/°C from table 2.2, page (5/8)
Gamma, Γ is the slope of the vapor saturation pressure vs. temperature curve shown on page (8/8)

Assumptions:

Relative humidity of the soil surface is 1.0. Thus the Modified Penman Equation calculates potential evaporation, not actual.

Temperature, net radiant energy, and wind speed are reduced by 3X to find the reduction factor.

Relative humidity is increased to that of Seattle, WA. Hr = 0.75

Calculations:

Modified Penman Equation:

$$E = \frac{\Gamma Q + 0.35\nu(1 + 0.15Ua)Pa(B - A)}{\Gamma + \nu A}$$

Input average INEEL values used in modeling:

B = 1/Hr = 1.538
A = 1.0

Equation from page (7/7)

$$\Gamma = 2.8e^{-5}T^3 - 9.0e^{-4}T^2 + 0.056T + 0.0923$$

$\Gamma = 2.8e^{-5}(5.15)^3 - 9.0e^{-4}(5.15)^2 + 0.056(5.15) + 0.0923$
$\Gamma = 0.361$ mm Hg/°C

Prepared By: B.G. Adams
Date: 3-18-02
Checked By: John Pellicer
Date: 19-Mar-2002

Equation from table 2.3, page (6/7):

$$Pa = 0.6108e^{\left[\frac{17.27T}{T+237.3}\right]}$$

$$Pa = 0.6108e^{\left[\frac{17.27(5.15)}{(5.15)+237.3}\right]} = 0.8815kPa$$

Convert Pa in kPa/°C to mm Hg/°C:

$$Pa = 0.8815\,{}^{kPa}\!/_{\circ C}\left(\frac{7.500617mmHg}{1kPa}\right) = 6.61\,{}^{mmHg}\!/_{\circ C}$$

Psychometric Constant from table 2.2, page (5/7) for elevation of 1600 m.
Convert v in kPa/°C to mm Hg/°C:

$$v = 0.056\,{}^{kPa}\!/_{\circ C}\left(\frac{7.500617mmHg}{1kPa}\right) = 0.42\,{}^{mmHg}\!/_{\circ C}$$

$$E = \frac{(0.361)(3.31) + 0.35(0.42)(1+0.15(14.18))(6.61)(1.538-1)}{0.361+(0.42)(1)}$$

E = 3.62 mm/day

Reduction for Modified Penman Equation using reduced temperature:

E_T = potential evaporation with reduced temperature
$T_R = 5.15/3 = 1.72$ °C
Γ_T = Gamma at reduced temperature
Pa_T = saturation vapor pressure at reduced temperature
RF = Reduction factor

Equation from page (6/6)

$$\Gamma_T = 2.8e^{-5}T^3 - 9.0e^{-4}T^2 + 0.056T + 0.0923$$

$\Gamma_T = 2.8e^{-5}(1.72)^3 - 9.0e^{-4}(1.72)^2 + 0.056(1.72) + 0.0923$
$\Gamma_T = 0.186$ mm Hg/°C

Equation from table 2.3, page (6/7)

$$Pa_T = 0.6108e^{\left[\frac{17.27T}{T+237.3}\right]}$$

$$Pa_T = 0.6108e^{\left[\frac{17.27(1.72)}{(1.72)+237.3}\right]} = 0.692kPa$$

Convert Pa kPa/°C to mm Hg/°C:

$$Pa_T = 0.692\,{}^{kPa}\!/_{\circ C}\left(\frac{7.500617mmHg}{1kPa}\right) = 5.19\,{}^{mmHg}\!/_{\circ C}$$

$$E_T = \frac{(0.186)(3.31) + 0.35(0.42)(1+0.15(14.18))(5.19)(1.538-1)}{0.186+(0.42)(1)}$$

Prepared By: B.G. Adams
Date: 3-18-02
Checked By: John Pellicer
Date: 19-Mar-2002

$E_T = 3.13$ mm/day
RF = 3.13/3.62 = 0.86

Reduction for Modified Penman Equation using reduced net radiant energy:

E_Q = potential evaporation with reduced net radiant energy
$Q_R = 3.31/3 = 1.103$ mm/day

$$E_Q = \frac{(0.361)(1.103) + 0.35(0.42)(1 + 0.15(14.18))(6.61)(1.538 - 1)}{0.361 + (0.42)(1)}$$

$E_Q = 2.60$ mm/day
RF = 2.60/3.62 = 0.72

Reduction for Modified Penman Equation using reduced wind speed:

E_{Ua} = potential evaporation with reduced wind speed
$Ua_R = 14.18/3 = 4.73$ km/hr

$$E_Q = \frac{(0.361)(3.31) + 0.35(0.42)(1 + 0.15(4.73))(6.61)(1.538 - 1)}{0.361 + (0.42)(1)}$$

$E_{Ua} = 2.67$ mm/day
RF = 2.67/3.62 = 0.74

Reduction for Modified Penman Equation increased relative humidity:

E_R = potential evaporation with increased relative humidity
$H_R = 0.75$
B = 1/0.75 = 1.333

$$E_Q = \frac{(0.361)(3.31) + 0.35(0.42)(1 + 0.15(14.18))(6.61)(1.333 - 1)}{0.361 + (0.42)(1)}$$

$E_R = 2.83$ mm/day
RF = 0.78

Conclusion:

The percent reduction shown in the following table represent a reduction in each parameter of 1/3. These show the effects of extreme changes in the climate on the amount of potential evaporation at the ICDF landfill.

Parameter	INEEL Potential Evaporation (mm/day)	Reduced Potential Evaporation (mm/day)	Average Percent Reduction in Potential Evaporation
Temperature	3.62	3.13	14%
Net Radiant Energy	3.62	2.60	28%
Wind Speed	3.62	2.67	26%
Relative Humidity	3.62	2.83	22%

 [redacted]

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Annex 2. Meteorological tables

TABLE 2.1. Atmospheric pressure (P) for different altitudes (z)

$$P = 101.3\left(\frac{293 - 0.0065z}{293}\right)^{5.26} \quad \text{(Eq. 7)}$$

z (m)	P (kPa)	z (m)	P (kPa)	z (m)	P (kPa)	z (m)	P (kPa)
0	101.3	1000	90.0	2000	79.8	3000	70.5
50	100.7	1050	89.5	2050	79.3	3050	70.1
100	100.1	1100	89.0	2100	78.8	3100	69.6
150	99.5	1150	88.4	2150	78.3	3150	69.2
200	99.0	1200	87.9	2200	77.9	3200	68.8
250	98.4	1250	87.4	2250	77.4	3250	68.3
300	97.8	1300	86.8	2300	76.9	3300	67.9
350	97.2	1350	86.3	2350	76.4	3350	67.5
400	96.7	1400	85.8	2400	76.0	3400	67.1
450	96.1	1450	85.3.	2450	75.5	3450	66.6
500	95.5	1500	84.8	2500	75.0	3500	66.2
550	95.0	1550	84.3	2550	74.6	3550	65.8
600	94.4	1600	83.8	2600	74.1	3600	65.4
650	93.8	1650	83.3	2650	73.7	3650	65.0
700	93.3	1700	82.8	2700	73.2	3700	64.6
750	92.7	1750	82.3	2750	72.7	3750	64.1
800	92.2	1800	81.8	2800	72.3	3800	63.7
850	91.6	1850	81.3	2850	71.8	3850	63.3
900	91.1	1900	80.8	2900	71.4	3900	62.9
950	90.6	1950	80.3	2950	71.0	3950	62.5
1000	90.0	2000	79.8	3000	70.5	4000	62.1

TABLE 2.2. Psychometric constant (γ) for different altitudes (z)

$$\gamma = \frac{c_p P}{\varepsilon \lambda} = 0.665 \times 10^{-3} \quad \text{(Eq. 8)}$$

$\boxed{\gamma = 0.665 \times 10^{-3} P}$

z (m)	γ kPa/°C	z (m)	γ kPa/°C	z (m)	γ kPa/°C	z (m)	γ kPa/°C
0	0.067	1000	0.060	2000	0.053	3000	0.047
100	0.067	1100	0.059	2100	0.052	3100	0.046
200	0.066	1200	0.058	2200	0.052	3200	0.046

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300	0.065	1300	0.058	2300	0.051	3300	0.045
400	0.064	1400	0.057	2400	0.051	3400	0.045
500	0.064	1500	0.056	2500	0.050	3500	0.044
600	0.063	1600	0.056	2600	0.049	3600	0.043
700	0.062	1700	0.055	2700	0.049	3700	0.043
800	0.061	1800	0.054	2800	0.048	3800	0.042
900	0.061	1900	0.054	2900	0.047	3900	0.042
1000	0.060	2000	0.053	3000	0.047	4000	0.041

INEEL

Based on $\lambda = 2.45$ MJ kg^{-1} at 20°C.

TABLE 2.3. Saturation vapour pressure (e°(T)) for different temperatures (T)

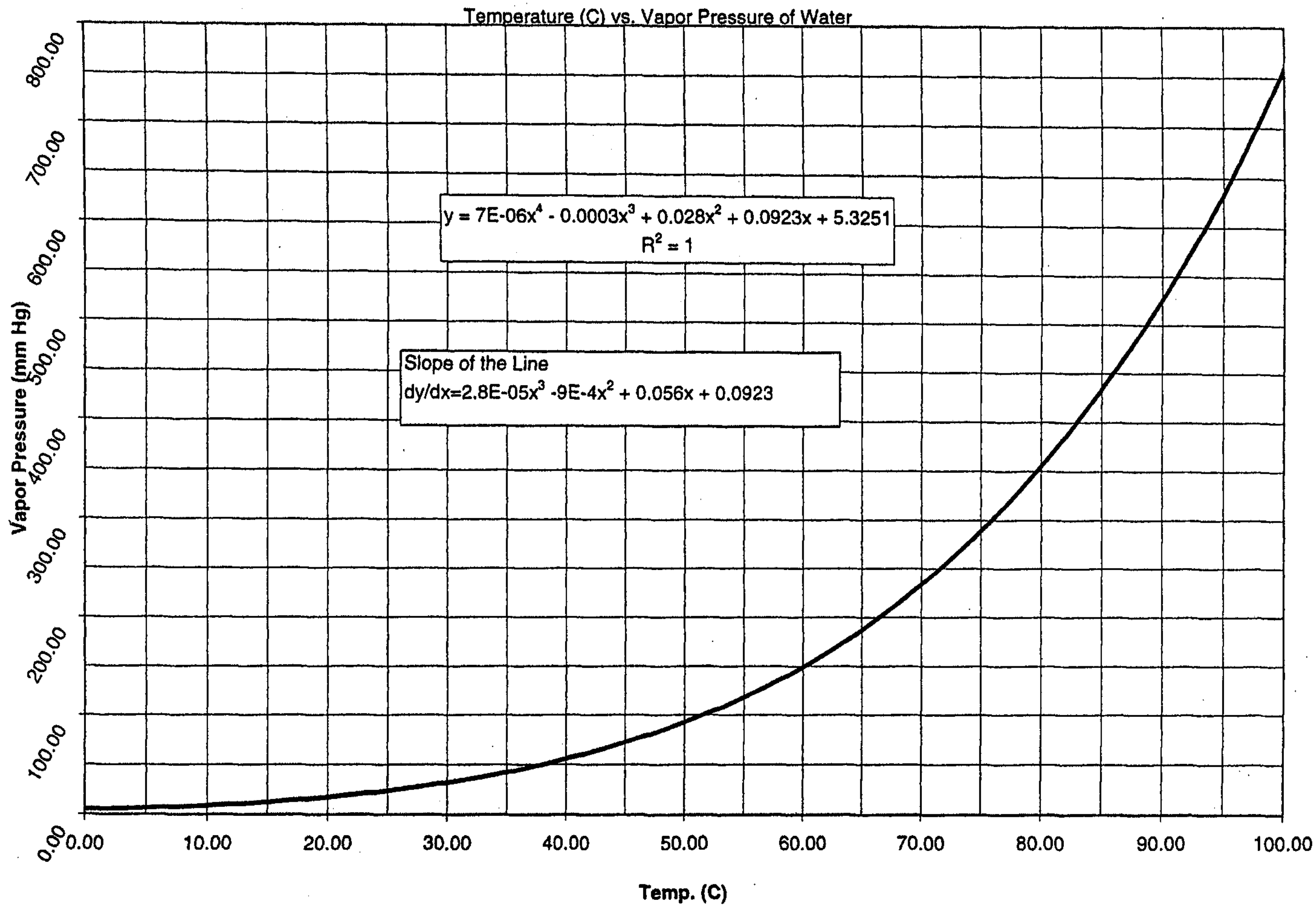
$$e°(T) = 0.6108 \exp\left[\frac{17.27T}{T+237.3}\right] \quad \textbf{(Eq. 11)}$$

T °C	e_s kPa	T °C	e°(T) kPa	T °C	e°(T) kPa	T °C	e_s kPa
1.0	0.657	13.0	1.498	25.0	3.168	37.0	6.275
1.5	0.681	13.5	1.547	25.5	3.263	37.5	6.448
2.0	0.706	14.0	1.599	26.0	3.361	38.0	6.625
2.5	0.731	14.5	1.651	26.5	3.462	38.5	6.806
3.0	0.758	15.0	1.705	27.0	3.565	39.0	6.991
3.5	0.785	15.5	1.761	27.5	3.671	39.5	7.181
4.0	0.813	16.0	1.818	28.0	3.780	40.0	7.376
4.5	0.842	16.5	1.877	28.5	3.891	40.5	7.574
5.0	0.872	17.0	1.938	29.0	4.006	41.0	7.778
5.5	0.903	17.5	2.000	29.5	4.123	41.5	7.986
6.0	0.935	18.0	2.064	30.0	4.243	42.0	8.199
6.5	0.968	18.5	2.130	30.5	4.366	42.5	8.417
7.0	1.002	19.0	2.197	31.0	4.493	43.0	8.640
7.5	1.037	19.5	2.267	31.5	4.622	43.5	8.867
8.0	1.073	20.0	2.338	32.0	4.755	44.0	9.101
8.5	1.110	20.5	2.412	32.5	4.891	44.5	9.339
9.0	1.148	21.0	2.487	33.0	5.030	45.0	9.582
9.5	1.187	21.5	2.564	33.5	5.173	45.5	9.832
10.0	1.228	22.0	2.644	34.0	5.319	46.0	10.086
10.5	1.270	22.5	2.726	34.5	5.469	46.5	10.347
11.0	1.313	23.0	2.809	35.0	5.623	47.0	10.613
11.5	1.357	23.5	2.896	35.5	5.780	47.5	10.885
12.0	1.403	24.0	2.984	36.0	5.941	48.0	11.163
12.5	1.449	24.5	3.075	36.5	6.106	48.5	11.447

TABLE 2.4. Slope of vapour pressure curve (Δ) for different temperatures (T)

ICDF Sensitivity Runs
Project #: 2470178

Prepared By: Brodie Adams
Checked By: (math only) Matt Warner
Checked By:



CRC Handbook of Chemistry and Physics

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Appendix F

Lower Cover Section Two-Dimensional SEEP/W Seepage Analysis

F.1 METHODOLOGY

Two-dimensional hydrologic modeling of a portion of the middle and lower part of the cover section was completed for the ICDF landfill using SEEP/W, Version 4 developed by Geo-Slope International Ltd. SEEP/W is a two-dimensional, finite element software package that models steady state and transient flow within soil systems. SEEP/W is formulated on the basis that the flow of water through both saturated and unsaturated soil follows Darcy's Law which states that:

$q = ki$

where:

q = specific discharge

k = hydraulic conductivity

i = gradient of fluid head or potentials

The governing differential equation (F-1) used to determine flow by SEEP/W is:

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial H}{\partial y}\right) + Q = \frac{\partial \Theta}{\partial t} \qquad \text{(F-1)}$$

where;

H = total hydraulic head;

k_x = hydraulic conductivity in the x-direction

k_y = hydraulic conductivity in the y-direction

Q = applied boundary flux

Θ = volumetric water content

t = time.

Under steady state conditions, the flux entering and leaving an elemental volume is the same at all times. The right side of the equation consequently goes to a value of zero and the equation can be rewritten as the following:

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial H}{\partial y}\right) + Q = 0 \qquad \text{(F-2)}$$

Water in liquid form can be considered to flow along a web of interconnected conduits within a soil mass. Decreasing the water content of a given soil effectively decreases the area of the conduits, thereby reducing the capacity to conduct water through the soil. When the soil is dry, the soil's ability to conduct water is drastically reduced, whereas, when the soil is saturated, the soil's hydraulic conductivity is at a maximum. Since the water content is a function of pore-water pressure and the hydraulic conductivity is a function of water content, hydraulic conductivity is a function of pore water pressure.

Unsaturated permeabilities and their corresponding pore-water pressure used for the various soil types modeled in this study were determined by laboratory testing. These soils are similar to the type of soils found at INEEL or can be processed from the locally available soils.

F.2 MODEL INPUT

The location of the cover section modeled is shown on Figure F-1. The cover section geometry modeled is shown in Figure F-2. This represents the worst case scenario since it has the greatest horizontal length which allows more infiltration. The cover section proposed for ICDF as designed is shown in Figure F-3 (2001_EDF281).The cover section that was modeled is shown in Figure F-4. The difference between the design cover section and the modeled section is the upper section (water storage component) was not included in the model. Percolation from this portion of the cover was previously modeled. The finite element mesh used to model the cover section percolation is shown in Figure F-5.

Figure F-4 shows different soil layers in the cover section. The Type 3 material was assumed to have the same soil water characteristic curve (SWCC) as Type 2 material. This allowed water to percolate downward into the lateral drainage layers providing more conservative model results. The SWCC used for the material types shown in Figure F-4 is presented in Table F-1. The SWCC shows the relationship between pore water suction and permeability. The SWCCs were obtained from GEO-SLOPE's (makers of SEEP/W) database of representative soils that have been collected from educational institutes, government institutes, government organizations, and private companies. The cover slope was modeled at 3% which is the worst case scenario after long term settlement (2001_EDF267) and 7% which is the slope after construction.

The boundary conditions consisted of a flux boundary along the upper model surface used to simulate inflow into the lateral drainage layer. It was assumed that once percolation entered the Type 3 material (bio-intrusion layer), it could not migrate vertically upward and could only move laterally or vertically downward within the model. A zero pressure boundary was placed on the right side (downslope) of the mesh to model the free draining Type 1 rip rap proposed around the perimeter of the ICDF. The mesh slope over the waste body is 3% which is a worst case scenario. The total width of the mesh over the 3% slope section is 135 meters which is the widest possible cover section. A total of 135 meters of this cover model extends over the waste with the additional 15 meters of the cover over the landfill perimeter. Vertical downward flux through the bottom of the clay overlying the waste was monitored along with the horizontal flux at the edge of the waste.

Table F-1. Soil Type Pore Water Pressure-Permeability Data.

Structural Fill		Type 1 Filter		Type 2 Filter		Soil Bentonite Liner	
Pore Water Pressure (kPa)	Permeability (m/sec)	Pore Water Pressure (kPa)	Permeability (m/sec)	Pore Water Pressure (kPa)	Permeability (m/sec)	Pore Water Pressure (kPa)	Permeability (m/sec)
-1.298	3.46e-6	-0.010	4.80e-7	-0.100	2.31e-5	-1.000	7.00e-10
-1.662	3.52e-6	-0.016	4.80e-7	-0.143	2.31e-5	-1.229	6.90e-10
-2.301	3.00e-6	-0.026	4.80e-7	-0.207	2.31e-5	-1.511	6.80e-10
-5.614	8.61e-10	-0.043	4.80e-7	-0.297	2.31e-5	-1.858	6.67e-10

Structural Fill		Type 1 Filter		Type 2 Filter		Soil Bentonite Liner	
-14.978	2.35e-15	-0.069	4.80e-7	-0.428	2.31e-5	-2.285	6.54e-10
-24.055	2.49e-16	-0.113	4.80e-7	-0.616	2.31e-5	-2.809	6.39-10
		-0.183	4.80e-7	-0.886	2.29e-5	-3.454	6.22e-10
		-0.298	4.80e-7	-1.274	2.18e-5	-4.247	6.03e-10
		-0.483	4.80e-7	-1.833	1.34e-5	-5.221	5.82e-10
		-0.078	4.80e-7	-2.636	7.69e-5	-6.420	5.59e-10
		-1.274	4.80e-7	-3.793	5.62e-8	-7.893	5.33e-10
		-2.069	4.80e-7	-5.456	7.70e-9	-9.704	5.05e-10
		-3.359	4.80e-7	-7.847	1.30e-9	-11.932	4.74e-10
		-5.455	4.53e-7	-11.288	3.75e-10	-14.670	4.41e-10
		-8.858	4.06e-7	-16.238	1.09e-10	-18.037	4.04e-10
		-14.384	2.65e-7	-23.357	3.60e-10	-22.177	3.66e-10
		-23.357	3.80e-7	-33.598	1.26e-11	-27.266	3.25e-10
		-37.927	3.93e-7	-48.329	4.06e-12	-33.523	2.83e-10
		-61.585	3.42e-10	-69.519	9.30e-13	-41.217	2.41e-10
		-100.000	1.58e-11	-100.000	1.82e-13	-50.675	1.99e-10
						-62.305	1.59e-10
						-76.604	1.22e-10
						-94.184	8.98e-11
						-115.800	6.31e-11
						-142.370	4.22e-11
						-175.05	2.69e-11
						-215.220	1.63e-11
						-264.610	9.50e-12
						-325.340	5.32e-12
						-400.000	2.89e-12

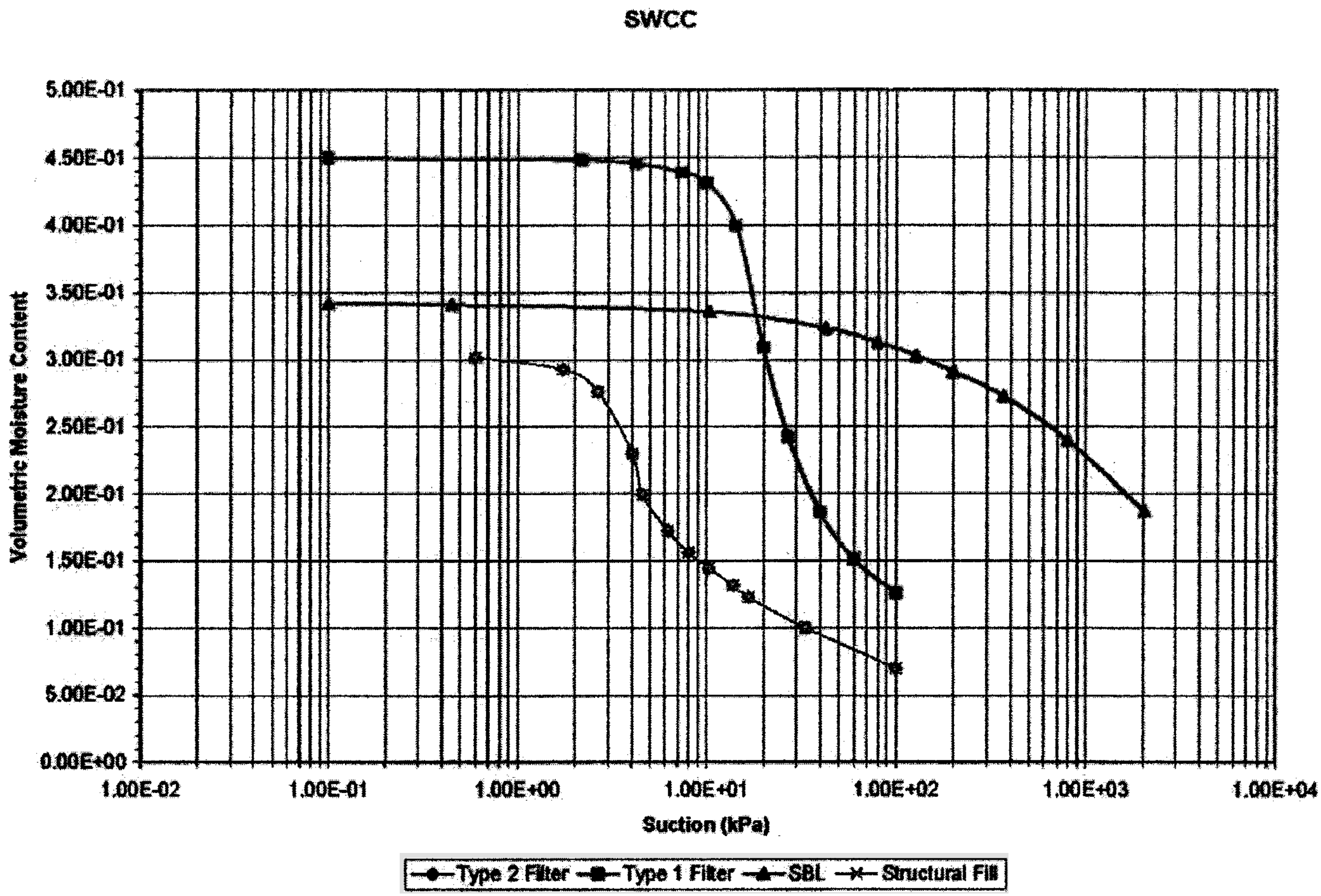


Table F-2. Soil Properties

Parameter	Structural Fill	Type 1 Filter	Type 2 Filter	Soil Bentonite Liner
Porosity	0.30	0.45	0.30	0.34
Description	Medium Sand	Silty Fine Sand	Medium Sand	Well Graded Clay
Saturated Hydraulic Conductivity (m/sec)	3.4×10^{-5}	4.8×10^{-7}	2.15×10^{-5}	7×10^{-10}

The Type 1 and 2 materials used for the SEEP/W modeling are similar materials to those used for the modeling of the upper section of the cover. The soil suction-permeability curves were modified slightly for the SEEP/W analysis to determine the best materials to specify for the cover construction. This was done to optimize the performance of the lateral drainage layer to minimize percolation through the bottom of the soil bentonite liner for the given input flux.

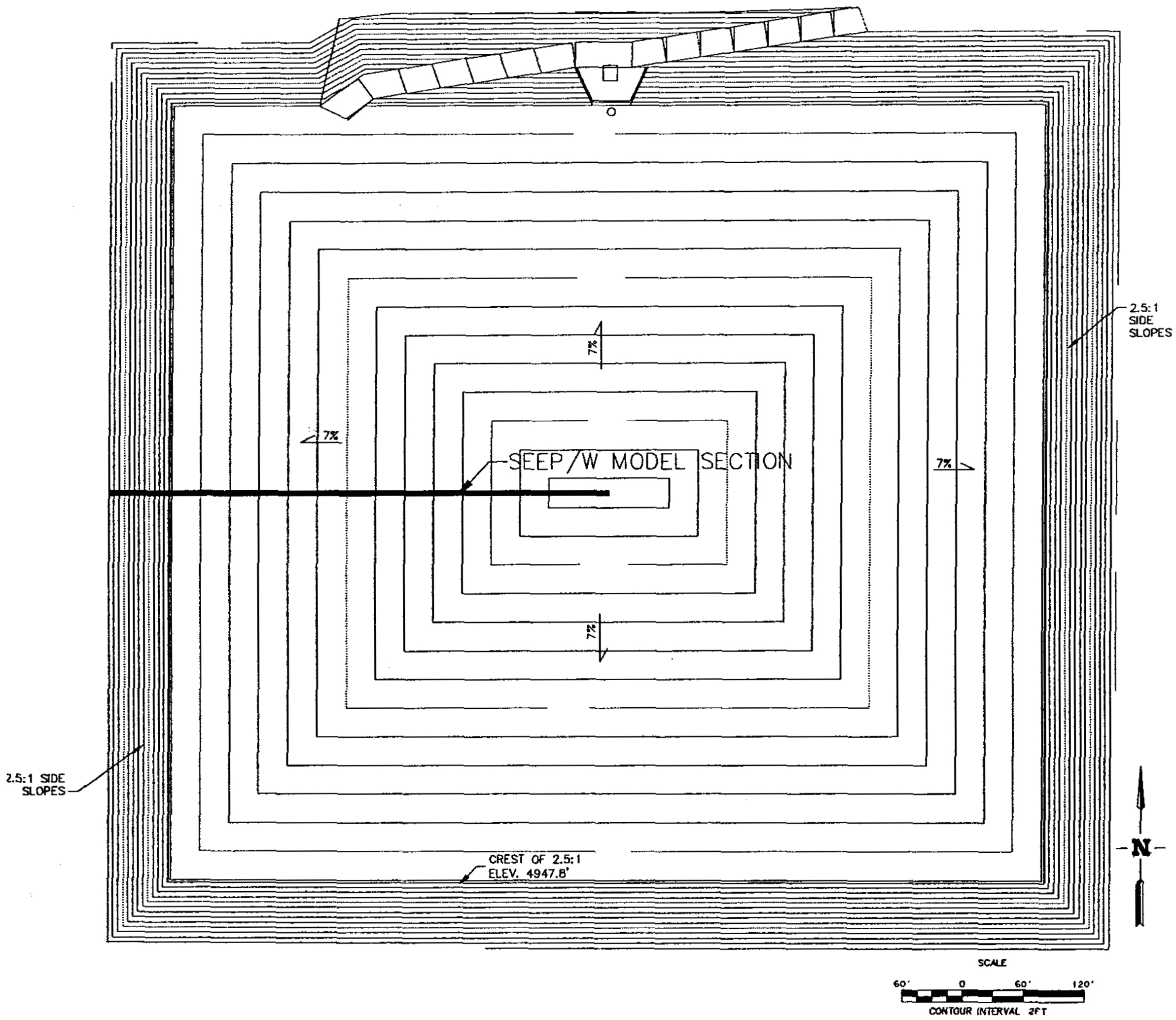


Figure F-1. Cover Plan and Model Section Location.

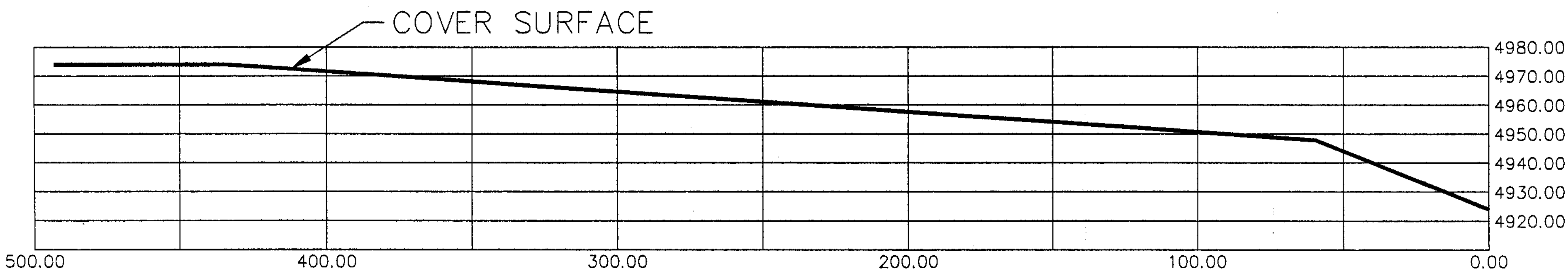


Figure F-2. Cover Section Geometry.

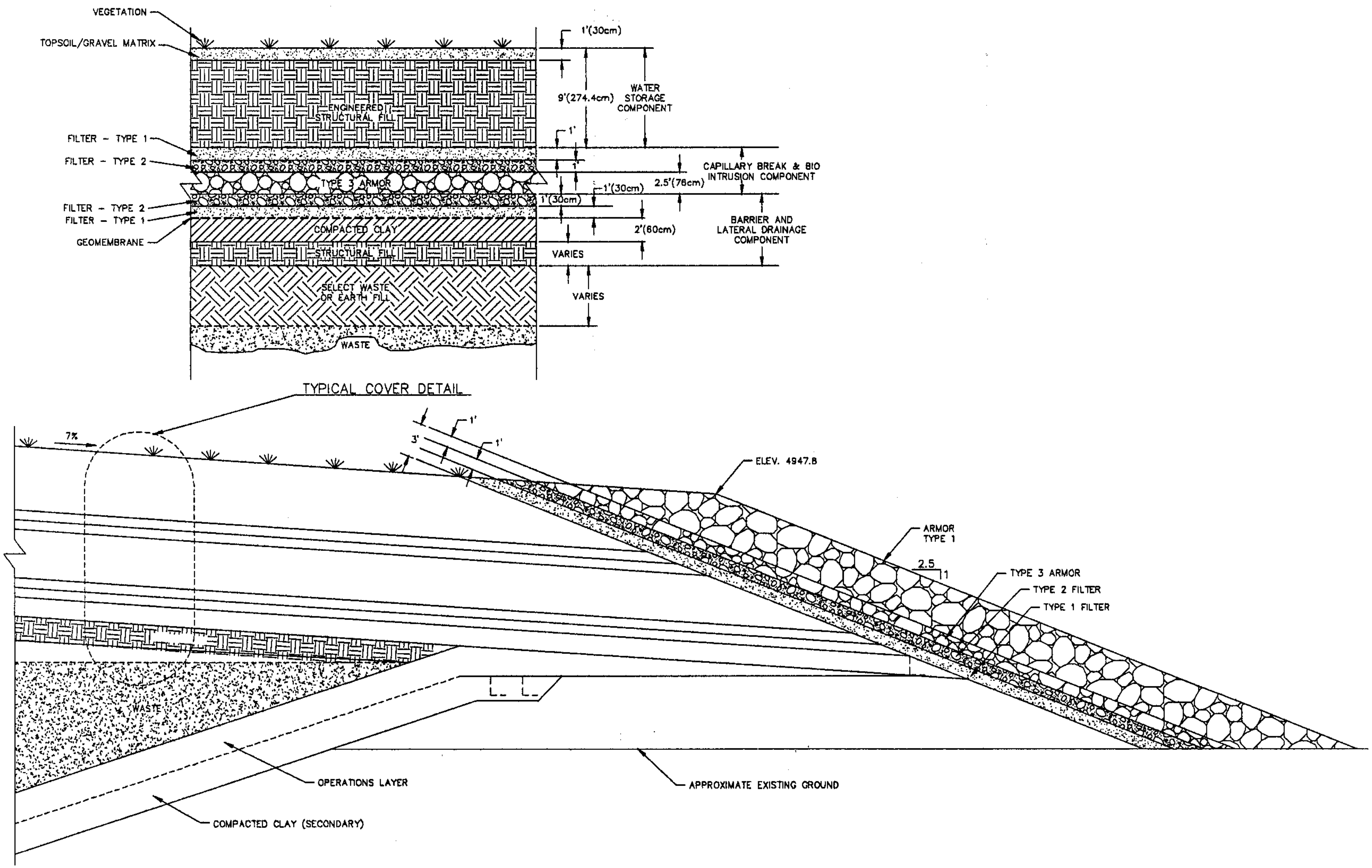
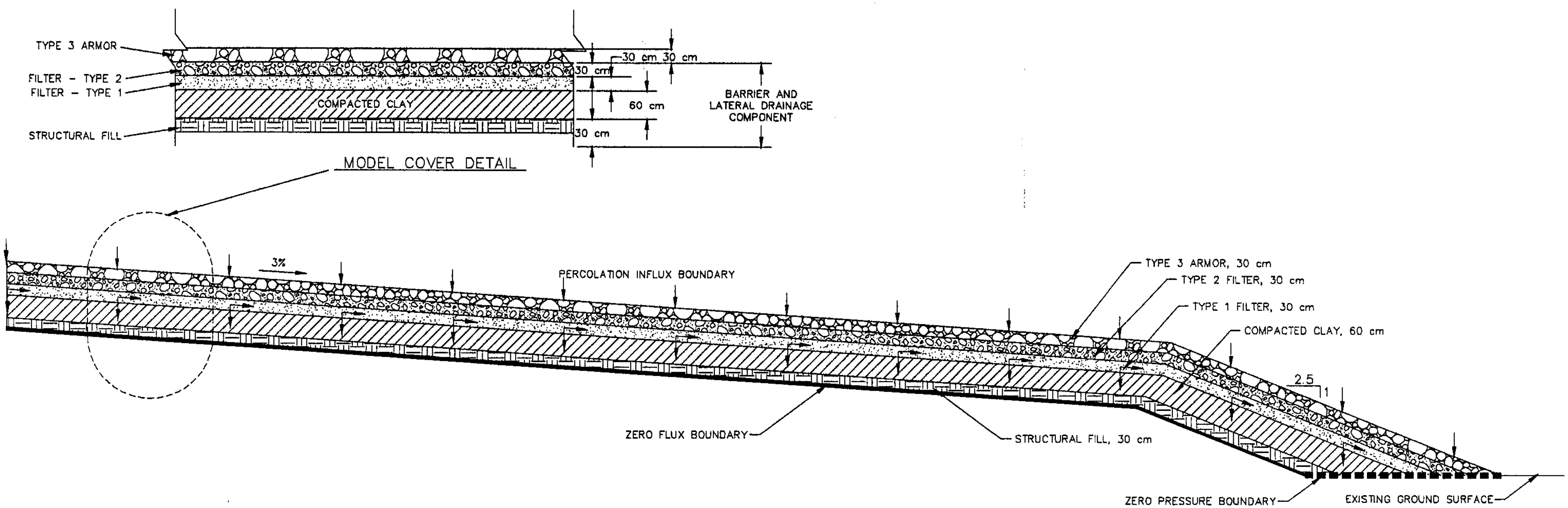


Figure F-3. Design Cover Section.



Note: Only one side of the cover was modeled since it is geometrically symmetric.

Figure F-4. Model Cover Section

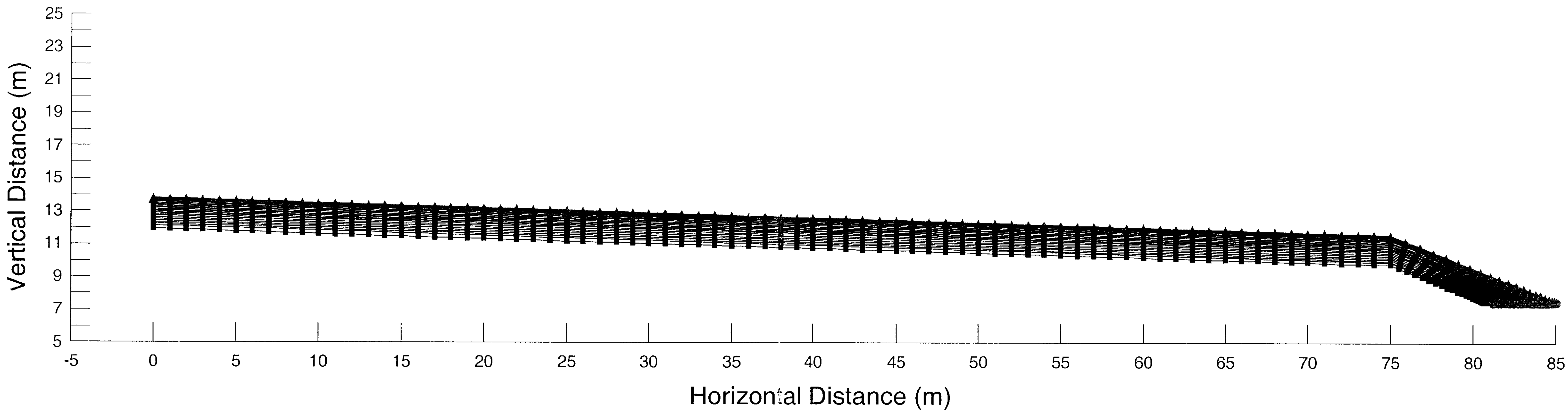


Figure F-5. Finite Element Mesh

F.3 MODELING

Eight different steady-state models were run for this exercise. Four models were run with a cover slope of 3% which is a worst case cover slope scenario and 7% which is the design cover slope. All the models utilized the same geometry and materials types with a range of inflow fluxes in the lateral drainage layer.

The 3% cover flux input to the top of the cover model was as follows:

- 0.4 mm/yr (0.001096 mm/day), the average percolation through the water storage layer based on Soil Cover modeling using the base case weather data;
- 0.46 mm/yr (0.00126 mm/day), the average percolation through water storage layer based on Soil Cover modeling using the worst case weather data;
- 0.8468 mm/yr (0.00232 mm/day), an arbitrary percolation value chosen to determine the sensitivity of cover surface influx with flux through the bottom of the clay cover;
- 1.00 mm/yr (0.00279 mm/day), an arbitrary upper bound percolation picked to determine the sensitivity of cover influx to flux through the bottom of the clay cover.

The 7% cover flux input to the top of the cover model was as follows:

- 0.4 mm/yr (0.001096 mm/day), the average percolation through the water storage layer based on Soil Cover modeling using the base case weather data
- 1.00 mm/yr (0.00274 mm/day), an arbitrary value chosen to determine the sensitivity of cover influx to flux through the bottom of the clay cover
- 1.25 mm/yr (0.00342 mm/day), an arbitrary value chosen to determine the sensitivity of cover influx to flux through the bottom of the clay cover
- 1.50 mm/yr (0.00411 mm/day), an arbitrary upper bound percolation picked to determine the sensitivity of cover influx to flux through the bottom of the clay cover.

F.4 MODEL RESULTS

The model results were monitored by observing the vertical flux through the bottom of the compacted clay portion of the cover. The vertical flux for the eight different models is summarized below in Figure F-6. Mass balance considering the influx on the cover surface compared to the sum of the vertical flux at the compacted clay base and horizontal flux at the waste edge was monitored for each model. Model mass balance was found to be within plus or minus 2.7% in all cases with most results less than 2%.

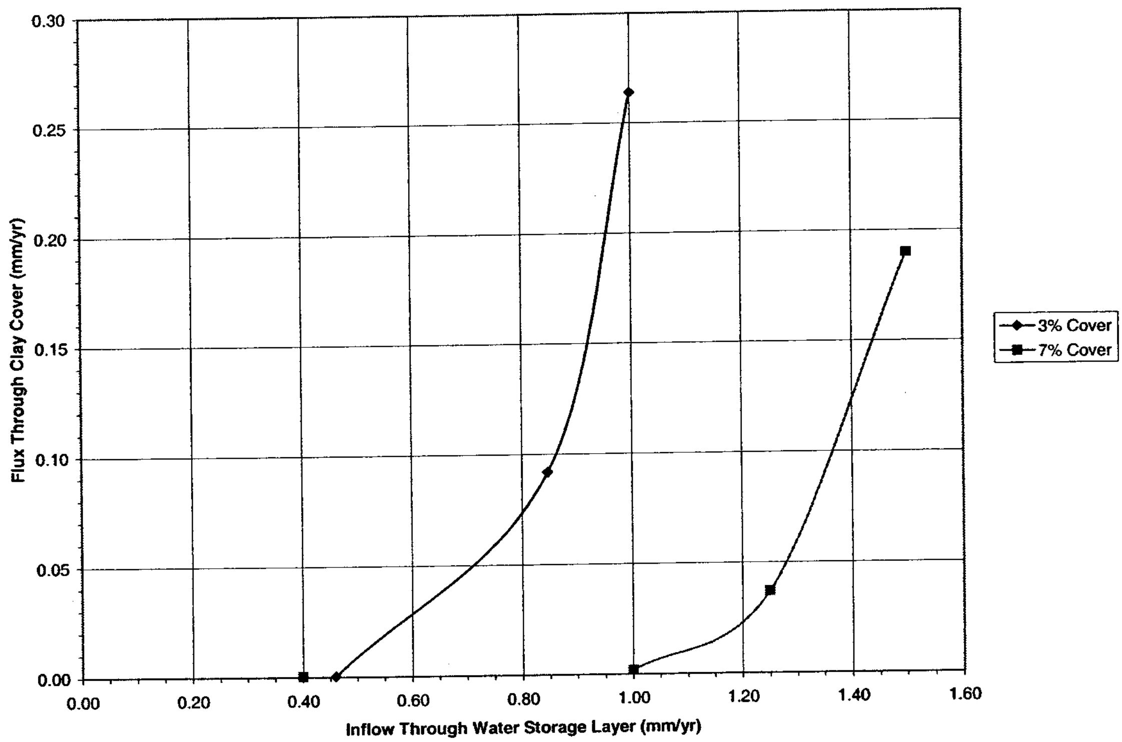


Figure F-6. SEEP/W Two Dimensional Seepage Analysis Results.

F.5 CONCLUSION

Based on an influx of 0.4 and 0.46 mm/yr as determined by the Soil Cover modeling, the cover system as designed will conduct less than 0.1mm/yr of infiltration into the waste body. Soil suction curves used for this model should be field verified prior to construction to ensure that actual soil parameters are similar to those used for the SEEP/W modeling.

F.6 REFERENCES

GEO-SLOPE International Ltd., SEEP/W For Finite Element Analysis, Version 4 User's Guide, 1999, Ontario, Canada.